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RANGE ESTIMATION TRAINING AND PRACTICE: A STATE OF THE ART REVIEW

Thomas J. Thompson

ARI FIELD UNIT AT FORT BENNING, GEORGIA

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This report summarizes the findings of laboratory, field, and military land-based range estimation research conducted since 1904. It includes a review of training techniques which have been demonstrated to be effective in field environments which are directly relevant to military requirements for such enhancement techniques. The result of the literature and field experimentation reviewed indicated that with practice, and by using aids to establish relative size relationships between known size targets and a

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reference, estimates of distance to the targets can be improved. The level of skill resulting from the present range estimation training in the US Army is not sufficiently high enough to conduct comparative program training effectiveness analysis research. The author recommends that a program of skill enhancement be developed at the small unit level that will train improved range judgements using perceptual cues, relevant to the units operational environment. Once a general base of ranging skill is established it would be appropriate to develop specific research plans for testing potentially effective interventions.

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RANGE ESTIMATION TRAINING AND PRACTICE: A STATE OF THE ART REVIEW

Thomas J Thompson

Submitted by:
Seward Smith, Chief
ARI FIELD UNIT AT FORT BENNING, GEORGIA

Approved by
Harold F. O'Neil, Jr., Director
TRAINING RESEARCH LABORATORY

U.S. ARMY RESEARCH INSTITUTE FOR THE BEHAVIORAL AND SOCIAL SCIENCES
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FOREWORD

The Fort Benning Field Unit has conducted investigations into the effectiveness and appropriateness of past and current range estimation training programs as part of its training effectiveness analyses for the US Army Infantry School (USAIS). While USAIS has sponsored a number of research efforts, there has been a general application of the results for improvements in training procedures and programs throughout the US Army. Range estimation training has been a basic concern for commanders and small unit leaders in the field since the days of Alexander the Great. In many respects, we know very little more now about the practical application of range estimation abilities and the development of estimation skills than we did decades ago. The Fort Benning Field Unit, as part of its planned TEA efforts has reviewed appropriate results from military and scientific research which suggest that the soldier can be trained to estimate range better. The implication is that enhancement of this ability impacts positively on other battlefield task performances, and on the overall combat effectiveness of the soldier, the combat unit, and the US Army.

The review of training and experimental work shows that many of the most effective training procedures are not new, in fact, they have been an important part of training associated with musketry, or rifle marksmanship since the era of World War I. The problem facing the US Army today in improving range estimation training for the soldier is more a matter of determining how best to apply proven techniques rather than determining what will work. The primary recommendation that stands out in the research to date is to focus on small unit leadership to conduct training in the environment in which the soldier is expected to operate. Range estimation training should become an active part of tactical training, and with time, should become spontaneous rather than a series of procedures which must be called to mind.

Further research is being undertaken to apply and quantify the results of this investigation of range estimation training as part of on-going individual soldier skills training effectiveness analyses. Efforts are being made to provide US Army leadership, through the USAIS, with information to improve training in the field which will enhance the ability of the individual soldier to estimate range.

EDGAR M. JOHNSON
Technical Director

RANGE ESTIMATION TRAINING AND PRACTICE: A STATE OF THE ART REVIEW

EXECUTIVE SUMMARY

Introduction:

A number of byproducts have been developed as a result of the US Army's efforts to improve the training of its soldiers through Training Effectiveness Analysis (TEA) programs. This report is the result of research which began in support of the US Army Research Institute's Fort Benning Field Unit TEA of rifle marksmanship training. It has grown out of the concern that we are not maximizing the effectiveness of training to improve ranging judgments associated with target engagement.

Accurate range estimation is critical to the use of some weapons, particularly when considering the example of target engagements at the maximum range of some antitank guided missles. Ballistic weapons that are dependent upon accurate range judgments must be considered as well. In general, many field operations require ranging judgments. This report is directed at the requirements for enhancing judgments and at the training which has been shown to improve estimation skills.

Procedure:

A literature search was undertaken to examine past attempts to investigate range estimation skills and improvements in related training. The focus of the search narrowed quickly to include only the research and training program results that had been developed and conducted in field settings. Laboratory perceptual research that could not be directly transferred to environmental settings were excluded. In many cases, however, such research served to stimulate the research that was considered appropriate for citation. Observations of soldiers performing during relevant training contributed to the information base used to develop this report as well.

Findings:

The body of literature, observations, and current training (US Marine Corps Scout/Sniper School) suggest that techniques and training procedures exist which can improve human perceptual skills in order to make more accurate range judgements using estimation methods. Procedures which include the skilled use of map and terrain comparisons, relationships between known-size targets and a reference, and familiarization with the environmental conditions of a given locale on estimates appear to contribute to improved judgments of range. Historically, many of the procedures described were part of marksmanship training programs. The US Marine Corps teaches these procedures effectively, though to a select population.

Utilization of findings:

The results and conclusions presented in this report serve to encompass potential solutions to range estimation training and performance problems faced by the US Army today. The US Army Infantry School has identified range estimation skill development as an area that needs investigation and improvement. This report supports the notion that the first step in improving the range estimation skills of our soldiers is to begin practicing proven methods in the environment in which they will be used. The skill must first be developed before research can be focused on specific enhancements to training. This research will contribute to training program development.

RANGE ESTIMATION TRAINING AND PRACTICE:
A STATE OF THE ART REVIEW

TABLE OF CONTENTS

	Page
INTRODUCTION	1
Background	1
Problem	2
Objective	2
LITERATURE REVIEW	4
Perceptual Literature	5
Military Literature	8
Related Research	12
DISCUSSION	15
US Army Training Applications	15
USMC Scout/Sniper Training	20
Training Procedures	23
Training Environment	25
CONCLUSIONS AND RECOMMENDATIONS	28
REFERENCE NOTES	32
REFERENCES	33

LIST OF FIGURES

Page

Figure 1. The Binocular Reticle 17

Figure 2. Front Sight Post/175 Meter Silhoutte Relationship 18

Figure 3. Range Card M60 Machinegun 24

Figure 4. Range Card, Tank (FM 17-12, 1977) 25

INTRODUCTION

BACKGROUND

The ability to correctly estimate distance is an essential characteristic of the good marksman and therefore should form an important element in the education of the soldier (Firing Regulations for Small Arms, US Army, 1904). Training soldiers to accurately determine ranges to distant targets by using estimation methods has remained an important skill development task for the US Army. While procurement of optical and electronic instrumentation, such as tank optical range finders and the more recently developed laser range finders, has reduced range determination problems in specific situations, this is not typically the case for the infantryman. The infantry soldier usually does not have access to sophisticated instruments to assist him in making routine distance judgements. In many cases a soldier must determine distances to potential targets using some method of range estimation. The general problems related to determining how to train individuals to accurately estimate ranges as well as having the requirement to make accurate range estimations remain as ever present concerns subject to systematic research by the military for decades (Harker & Jones, 1980).

A variety of estimation procedures have been used in military settings to deal with the problem of determining ranges. These procedures have been tested extensively in some cases and generally accepted without formal testing as conventional wisdom in others. Some are presented in current field manuals and training circulars, as well as in resident courses of instruction at various branch service schools. The relatively broad dissemination of available military range estimation information has not, however, solved a continuing problem for the US Army. Soldiers trained in conventionally accepted ways, as exemplified in the soldiers manuals (FM 7-11B1, 1976), have continued to make range estimation errors in magnitude equivalent to errors made by untrained individuals (Caviness, Maxey and McPherson, 1972).

In reviewing range estimation methods, training methods and techniques, as well as considering perceptual variables which relate specifically to the land-based range estimation problem, this review effort being reported has examined laboratory findings and the field testing of methods considered appropriate for military requirements. A number of research based issues have been identified and possible sources of training problems have been examined which include:

a. Difficulty may exist in training human beings to the extent to which they can improve estimation skills beyond existing individual levels of ability.

b. The task being trained, or the perceptual skills being enhanced, may not improve range estimations in military settings; or for all soldiers.

c. Existing procedures or training methods may already contribute maximally to improved human performance in military range estimation and if so, can they be effectively improved upon?

d. Is the existing effectiveness of training range estimation procedures less than optimal because of short comings in training doctrine and/or related policies?

e. What standard, assuming the soldier can be given appropriate training, can be achieved for field range estimations?

While not a totally inclusive list, these issues served as the anchor points for this research and served to direct recommendations for improved range estimation training and hopefully subsequent performance in field settings. A vast body of available literature on visual perception was not considered appropriate for this review because it was either too laboratory specific, and therefore not reasonably transferable to practical military settings, or it dealt with perceptual cues associated with specific environmental conditions beyond the scope of land-based range determinations (i.e., air-to-air or ground-to-air estimations). These additional areas have been examined in part in a general review of the perceptual literature (Hodge, 1981).[1]

PROBLEM

In older US Army training literature, range estimation errors of 10% or less were considered to meet the accepted standard (Turner & Fulmer, 1917). Field observations over the years, however, reveal typical errors which are at least twice as large in many cases (Schmidt, 1956). Results of the field observations have approximated the results of untrained subjects guessing, and also met what has become the new standard of 20% allowable error which is set forth in the soldier's manuals (FM 21-2, 1981). A consideration for inquiry and review of relevant literature is raised regarding range estimation training. At present, the major problem being faced is training the soldier to improve his range estimates and for his leaders to know how well this task can be trained and performed.

OBJECTIVE

The principle objective of this review has been to identify the most effective and appropriate approaches to enhancing range estimation skills

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[1]The author wishes to acknowledge the value of the research conducted by Dr. Hodge under contract number DAHC 19-77-C-0057 which included a proposal for a training facility devoted to the development of estimation skills. This effort provided clearly adaptable concepts.

used by the infantryman through improved training procedures and the use of aids which he might typically possess. In reviewing current training procedures for range estimation and the literature associated with perceptual research, the objective has been to identify what works. Research findings have been viewed in terms of transferability to field settings. In general, this pragmatic approach has been taken with a limited presentation of perceptual theory in support of this area of research. It has been found in recent research efforts related to weapons training (Smith, Osborne, Thompson, & Morey, 1980) that a considerable amount of conventional wisdom related to a given training issue, or objective, has been available in the past but has been discarded over time. The strong possibility of this having also occurred in the training or range estimation skills was considered during the review of military literature and training practices.

LITERATURE REVIEW

Range determination is basically the process of finding the distance between two points and commonly the associated phenomena considered under such tasks are size-constancy and size-distance problems (Ono, 1970). The term distance refers to the extent between two points on the medial plane, e.g., the generally horizontal terrain in front of an observer in a military field setting. The two types of extents on the medial plane which can be estimated are egocentric and exocentric extents (Ono, 1970). When one point is the observer and the other a distant point, the extent is egocentric or absolute. When two or more distant points do not include the observer, they represent exocentric distance (Gogel, 1977). Size, according to Ono's review (1970), can be described as the extent between two points in the frontal or vertical plane which can be independent of the location of the observer. Ono (1970) further considered distance perception, where the emphasis has traditionally been on determining what information derived by the observer from interactions with the environment is used to make judgements. A number of lists of cues to distance and depth have been developed (Gibson, 1950; Ittleson, 1960) which focus on the types of information used to determine distance. Knowledge of depth cues alone may not be sufficient to prepare soldiers for distance estimation in the field.

Range determination is usually an egocentric task, that is, it involves an observer at one point determining the range from this point to a target. Exocentric ranging decisions must be made as well in the military where the observer must determine the distance, and/or depth, which exists between two distant targets. The purpose of determining range in military situations may be to provide information about a target location or to consider engagement possibilities. Many modern antitank guided missles (ATGM) require, fundamentally, absolute range determination. While other variables must be considered, such as sufficient exposure time for engagement, these weapons require simply that a target be determined to be within range. Other primarily ballistic weapons such as rifles and artillery require not only absolute ranging information (in/out of range?) but discrete ranging information as well (how far?). Ballistic weapons require relatively accurate determinations of distance for effective use. While making both absolute and discrete distance judgements accurately represents the basic military problem addressed by this research review, a number of variables appear to affect human sensory perceptions which are used in making these field based judgements. A review of the literature related to human visual perception and training for range estimation has shown that while much is known, conflicts exist pertaining to the relative contributions of various components and cues in different settings. In other related research efforts the perceptual literature has been examined at length (Frederickson, 1970; Hodge, 1981; Horowitz, 1964). The purpose of this review, however, is to identify those variables which most clearly effect the training and/or mediate the decisions of soldiers required to determine ranges accurately.

PERCEPTUAL LITERATURE

Perception, as defined by Gibson (1959) is, "the process by which an individual maintains contact with his environment." In Gibson's work the distal stimulus, or object being viewed, is not as critical as the proximal stimulus or retinal image of the object which is the individual observer's unique perception of the object. A number of classes of variables tend to mediate the perceptions of the observer. Some of these are observer centered and comprise physiological and psychological components. The more physiological of these include accomodation and convergence which are muscle-related processes associated with eye focus and single images. These have been considered to be more influenced by, rather than influencing perceived depth (Ittelson, 1960). Motion parallax, referring to different angles between observer and target object which occur and are perceived as the object moves on the medial plane, is questioned as a contributing cue in a cluttered environment, such as is common in field settings (Selvitelle, 1974). Motion parallax has been described in research as a component of action perspective rather than as a depth cue itself (Gibson, Gibson, Smith, & Flock, 1959). Angle of regard, which describes angular differences in the line of sight, may act as a component for depth. The cue of awareness of familiar size in the target object has been explored as well. In laboratory settings the consideration of these egocentric perceptual cues has proven important at the relatively close ranges of a few meters or less. Binocular cues, which are important in depth research, may be limited to as little as 20 feet from the observer when stereopsis is found to be in conflict with other depth cues, such as color contrasts, background clutter and atmospheric attentuation which are found in field settings (Harker & Jones, 1980). With the exception of familiar size which is effective to great ranges, Gogel (1977) states that these cues are imprecise generally beyond a few meters.

Frederickson (1970) lists organismic variables which he interprets as influencing perception and the general sensory state of an organism in his study of shape perceptual judgement. Frederickson cites the work of Bruner and Goodman (1947) who point out that behavior is influenced constantly by the need, motivation, learning, and experience of the organism, or person. He considers these egocentric variables which are more psychological and multidimensional as contributing to the difficulty of accounting for individual differences in perception and behavior. These variables are past experience, intelligence, and perceptual style. Prentice (1947) suggests that perception is idiosyncratic and is the primary contributor to individual differences in behavior. From a functional point of view, observer tendencies represent the ability of an observer to make accurate distance judgements, even in the presence of considerable stimulus ambiguity, or under reduced cue conditions (Hodge, 1981). Reported findings related to visual perception support the notion that individual differences can be problematic in research. This is most noticeable in the frequent occurence of large intersubject variability in work on space and distance perception (Erikson, 1974; Kottas & Bessemer, 1979; Stark, Wolff, and Haggard, 1961).

Exocentric cues, or those more related to the environment rather than to the observer also contribute to the observer's perception of space and distance. Frederickson (1970) identified these as focal variables, or as independent variables which describe physical characteristics of the stimulus object(s) and the relationship the stimulus has to the surrounding environment. These variables included target shape, orientation of the target object, and depth cues. Contextual stimuli were included as well since the retinal image of a target object may blend with any surrounding stimulus (Bevan, 1968). While Frederickson found controversy regarding the effects of these variables, particularly when results of laboratory and field research were compared, it was clear that it has been common to limit the stimulus to simple shapes in field settings thus reducing the interactive effect of these variables as much as possible (Schmidt, 1956; Fried, 1961; Oatman, 1963). An ancillary finding from reviewing previous range estimation research, where care had been taken to simplify the target object, was that a bright white or yellow color had been used to aid in detection and simple geometric targets used to reduce shape influence respectively. This artificial coloration, at a distance, provided contrast with the target surroundings and according to related research findings influenced the interpretation of the depth cues received by the observer (Ferris, 1971; Fried, 1961; Ittieson, 1960; Oatman, 1963). Other studies have either combined the use of simply shaped targets and natural targets, or they accepted any extraneous variance which resulted from using irregular shaped targets (AMRL, 1945; Caviness, Maxey, & McPherson, 1972; Schmidt, 1956). While much is to be learned about range estimation from many of the previous efforts, the ones which took place in field settings and used realistic targets have provided the most pragmatic results for military applications.

The environmental, exocentric cues which most often appear to be used in military range estimation are the classical depth cues of linear perspective, texture gradient, interposition, aerial perspective, medial plane height, and familiar size. Linear perspective refers to the apparent covergence toward the horizon of similarly sized objects placed at regular intervals in depth from the observer. This simply presents the application of Euclid's Law on space. Texture gradient, which Gibson (1950) called "gradient of density of texture" also describes this tendency to see a systematic variation from coarse to fine texture on a regular surface as distance is perceived. Interposition describes the perception of depth between objects when one overlaps another in the field of view. Aerial perspective describes the effects that atmospheric conditions have on perception of distance. Distant objects tend to lose sharp contrast and bright color over distance as a result of atmospheric attenuation. Bright objects appear to be closer to the observer than subdued ones at the same distance (Ittelson, 1960). Light and shade are usually indications of depth and contour defining the surface gradients of an object rather than as indicators of distance, (Harker & Jones, 1980). Height in the medial plane refers to the perceived height of the object in relationship to the horizon. Given no other cue, an object perceived as being closer to the horizon will be considered more distant than one lower in relationship to the horizon.

Apparent, or familiar size is the last "classic" depth cue which Gibson (1950) considered to contribute to distance perception. Later research produced findings which suggested that familiar size could be considered as the primary cue differentiating between relative and absolute distance (Gogel, Hartman, & Harker, 1957). In this context, observation of a target object at maximum range established an absolute perception of the target which could be used to make subsequent relative judgements of other lesser distances.

Hodge (1981) reviewed the perceptual literature and found a number of studies which supported the importance of relative size as a critical cue to distance determination. Relative size is a cue which results from different retinal images produced by the simultaneous or successive presentation of two or more similarly shaped objects. The theoretical development of actual and perceived distance and depth Hodge expressed is based on the work of Gogel (1964) and Ono (1970) primarily. The review points out the relationship of the perceived size of an object or target on the frontal plane to its distance. The physical size of an object is perceived by the corresponding retinal image size, or the visual angle of the object as seen by an observer. Familiar or assumed size refers to an observer's memory of, and past experience with, an object (Hodge, 1981). The apparent size of a familiar object yields much meaningful information regarding its distance from the observer. Hodge (1981) argues that though there are reservations regarding Gogel's perceptual model (Epstein, Park, & Casey, 1961) the role of relative and familiar size cues to relative depth are fairly reasonable cues to space perception. Ono (1970) states that "familiar size can serve as a source of information for scalar tasks because familiar objects yield a specific retinal image size at a given distance, and this, in conjunction with the knowledge of the frontal extent of the object, can be utilized as information for the egocentric extent between the observer and the familiar object." This position, simply stated is that given the perceived size of a familiar object, the distance is defined by a geometrical size-distance relationship (Kaufman, 1974). This position has been supported by the earlier efforts of Kilpatrick and Ittelson (1953) who state, "a retinal projection or visual angle of given size determines a unique ratio of apparent size to apparent distance." The use of egocentric cues alone does not, according to Gogel (1977), provide precise enough information to account for accurate distance judgements obtained in research. Rather the exocentric cues of retinal disparity, relative size, and relative motion parallax are much more precise, as is the resulting retinal representation of the information provided by these cues (Hodge, 1981). Gogel (1964) relates familiar or assumed size to past experience and later (1977) establishes a link between awareness of familiar size as an egocentric cue and the exocentric relative size perception in the medial plane. This model has been explored in research and training. Relative size has been a cue used military range estimation literature for decades (FM 21-2, 1981; FM 23-67, 1964).

MILITARY LITERATURE

Historically, the standards for range estimation in the military have called for error magnitudes to be no greater than plus-or-minus ten percent (Caviness, et. al., 1972). In military training literature this magnitude of error has been supported and used as a standard. The Firing Regulations for Small Arms in the 1900 era required accurate range estimation to serve as part of the criteria for small arms qualification (Bell, 1903; FRFSA, 1904). To be considered qualified as a sharpshooter (highest level of proficiency) a firer had to not only shoot well but estimate, with 90 percent mean accuracy, the distance to five consecutive target silhouettes placed at distances between 500 and 1000 yards. Failure to achieve this level of accuracy lowered the marksmanship qualification level of the individual even if his demonstrated firing performance was measured to be at a higher level of proficiency (FRFSA, 1904). Training programs were used to develop the individual soldier's ability to estimate range which while improving most soldiers' abilities, would bring only the most proficient individuals to the highest established standard. In the following decade, Turner and Fulmer (1917), stated that "many thousands of estimates using this method (using only unaided eyes) have proven that it results in an average error of 12 1/2 per cent." In this context Turner and Fulmer (1917) found that this was an average across estimates by many observers. Some observers clearly were better, even without training, and some were worse. Range estimation accuracy was required in machine gun training of this era as well. In Machine Gun Known Distance Practice and Qualification Tests (MGKDPQT), Section 23 of the Machine Gun Service Regulations, an individual was tested and had to accurately estimate the range to four silhouettes or target individuals at ranges between 600 and 1500 meters with no greater than 15 per cent average error to pass this portion of the training (MGKDPQT, 1919). Again, a program was included in the manual which prescribed range estimation training. More recent manuals have continued to present training programs and estimation aids as well (FM 17-12, 1977; FM 21-2, 1981) though the established standard for estimation error magnitude has increased to 20 per cent for initial entry training (FM 21-2, 1981). This new standard has been established as a global criterion with no proficiency strata established to recognize performance differences. This differs from earlier standards, which allowed for (and included the recording of) performance differences that existed. (FRFSA, 1904).

The systematic research on range determination capabilities has been important to the military for decades (Bostock, 1915; Merkatz, 1915). Since World War II, however, more specific and detailed research findings have been available which have dealt with range determination issues in land, air, and interrelated environments such as air-to-ground conditions. Of those which were oriented to land-based range determination, many have provided results which support commonly used military training procedures and what has been accepted as conventional wisdom.

An Armored Medical Research Laboratory (AMRL, 1945) study found that untrained and unaided observers (N=175) under a variety of viewing conditions had a tendency to underestimate well defined bright targets across tested ranges and to generally overestimate partially hidden targets, or those observed in fog or under limited lighting conditions. More than one half of the observers in this study were estimating ranges to targets which were located at distances between 117 yards and 1880 yards from the observer with average errors in excess of 20 percent (error = 26.6%). Less than one third were able to consistently estimate with less than 10 percent error in estimation. It was thought that though no formal training was provided, familiarity with urban targets contributed to a smaller error magnitude for this task. There appeared to be no significant demographic or physiological variable which predicted innate ranging ability.

A study which addressed ranging to aircraft targets (Kappaul, 1945) is relevant in that the subjects were limited to only a few practice trials before testing. Kappaul (1945) found that corrective reinforcement of erroneous judgements reduced subsequent judgement errors. On pretraining trials only 17 percent of the subjects (N=164) were able to estimate the 1500 yard target range (for optimum antiaircraft gun engagement) with less than 15 percent error. After training trials, 60 percent were capable of judging when the target aircraft reached 1500 yards range with less than 15 percent error.

Gibson and Smith (1952) investigated the effects of corrective reinforcement on familiar/known size-at-a-distance judgements made using photographs and found performance improvements. They were concerned, however, that the photographs provided easily learned extraneous cues which did not necessarily reflect appropriate distance judgement learning (Gibson and Smith, 1952). Later, Gibson (1953) generally surveyed the area of distance judgement performance and the effect of controlled practice finding that a positive influence on performance existed. Gibson conducted further practical investigations of the effect of corrective reinforcement (Gibson & Bergman, 1954) and demonstrated, in a relatively flat field setting (grass playing fields), that this method improved absolute estimations of distance. Gibson and Bergman (1954) found a 79 percent positive transfer from training to test trials over slightly different ranging courses. They did suggest that terrain differences, being minimal, and the immediacy of testing after training may have contributed to an artifically high level of transfer. Later experimental work (Gibson, Bergman, & Purdy, 1955) showed lower transfer levels when greater variation in experimental conditions existed. The field experiments in the Gibson, Bergman, and Purdy (1955) study did produce significant differences between the judgements of trained observers and untrained ones (N=70). A trial course was used to teach scalar distances for approximately 20 minutes. All subjects, trained and untrained as well were transported to another site for testing. On a total of 18 judgements per subject of targets ranging between 52 yards and 395 yards, the trained subjects performed significantly better. The training course presented ranging increments between targets of 25 yards from 25 yards to 300 yards. Gibson, et. al. (1955) found that the trained subjects underestimated more during testing at the longer ranges used on the experimental terrain (beyond 300 yards) which they attributed to a tendency to identify the training maximum range (300 yards) as an "end anchor" for subsequent judgements. It was suggested that the subjects transferred the upper limit of the scalar cues learned during training for judgements during the experiment (Gibson, et. al., 1955).

Schmidt (1956) conducted a study using ROTC cadets as untrained subjects (N=550) in a series of field experiments to determine the effectiveness of corrective reinforcement training and the use of mil-scale binoculars (standard M-3, mil-radian scale) to improve range judgements. Schmidt (1956) found that using corrective reinforcement decreased the biases in earlier estimation errors and consequently decreased the average estimation error as well.

Dispersions in range estimations were reduced significantly with the use of binoculars (the subjects received instruction and drill in their use) to judge distances to targets of known size. The use of binoculars allowed estimates which were approximately 50 percent more accurate for targets of known size than for targets of unknown size. It was inferred by the results, according to the author (Schmidt, 1956), that binoculars with a milscale reticle did not significantly improve estimates to targets of unknown size across the range of target distances (365 yards to 1684 yards). When binoculars were used and subjects knew target sizes, and had received corrective reinforcement training, their average absolute error of true range was 21 percent. When given binoculars but not knowing target size nor having received corrective reinforcement training, subjects had average absolute errors of 36 percent in estimating true range (Schmidt, 1956).

Fried investigated the effects of elevated points of observation on the estimation of range (1961). The independent variables investigated were the amount of time allowed for estimation and the elevation above the medial plane (terrain). The subjects (N=22) did not receive any training nor did they receive corrective reinforcement for errors in estimation. The regular shaped targets (4x6 foot rectangles) were painted yellow to ease detection and identification. It was found that the time allowed for estimation had little effect. This finding supported subjects reports that the estimation was made almost immediately after the target was seen (Fried, 1961). Targets beyond the range of 1100 yards were included in the study but observers either could not locate them, or took an inordinate amount of time searching for them (target ranges were 50 to 1102 yards). Observers had a tendency to underestimate at short ranges and lower altitudes. There was a consistent tendency for accuracy to drop with increased elevation for observation between 100 yard targets and 700 yard targets, however, at the longer ranges (1100 yards) higher elevations resulted in slightly improved estimations (Fried, 1961). Error was found to be roughly a linear function of increased range beyond 250 yards. The extremely large error found below 250 yards (60% to 75% errors in estimates of the ground range) was attributed to inexperienced observers. Errors beyond 250 yards, while not as gross, did exceed typical errors made by guessing at all ranges.

Goldstone and Oatman (1962) conducted a study with helicopter pilots as subjects (N=18) which provided insights into range estimation under test conditions similar to the elevated range estimation work of Fried (1961). The subjects were to estimate range to a target (M-48 tank) from elevations of 50, 100, and 150 feet (Goldstone and Oatman, 1962). Fried (1961) had used 25.5, 71, and 105 foot platforms. Goldstone and Oatman (1962) found that with experienced pilots having some range estimation experience, and a short training course which provided error corrections, only 20 percent of the subjects had overestimates of no greater than 9 percent and underestimates of no greater than 6 percent. Course and altitude variations did not produce significant differences in measured performance. The training course used before testing in this study had target points located closer and more distant than those on the test courses. The practice course was marked with targets beginning at 200 meters and extending to 2200 meters. The test course targets began at 250 meters and extended to 1800 meters. A strong tendency to underestimate at the closer ranges (200 to 400 meters) was found but lessened at the longer ranges. This appears to support previous findings (Gibson, et. al., 1955) of underestimation in this range band and might suggest that with the training course providing an end anchor more distant than the test course (Goldstone and Oatman, 1962), the earlier conclusions were supported as well. In the earlier study the limited range (300 to 400 yards) was the upper limit of the training and the test. Target types, test terrain, and subject experience differ greatly between the two research efforts, and to suggest that direct correlations of findings existed would be questionable at best. Goldstone and Oatman (1962) suggested that their findings might be different if greater terrain variations had been available for training and testing.

In a later study, Oatman (1963) conducted preliminary comparisons of range estimation using black-and-white television and the unaided eye with enlisted soldiers at Aberdeen Proving Grounds (N=25). Extremely small errors in estimation were found during this study. For example, the mean estimates for both the unaided observation and the television view of the known-size targets at 1000 yards were 970.7 yards and 1012.7 yards, respectively. Targets ranged from 100 to 1000 yards and at most, the mean error was less than 3 percent at any given range. In this study (Oatman, 1963) the subjects trained at the same target ranges they were tested on. The author cited work by Gibson and Smith (1952) where it was suggested that subjects are likely to learn rather specific cues in a photograph during practice and are going to improve their distance estimates by cue association during testing. Oatman (1963) suggested that the comparatively accurate estimates in both modes might have been derived from specific cues learned during training. The television screen provided some cues to relative size relationships to the known size target and the unaided observation took place through a rectangular opening in a plywood panel used to mask outside stimulus and to match closely the field provided by the television screen. These relative size relationships may have been learned during training and reinforced by testing at the same ranges trained.

In a more recent study, range estimation and target detection times were tested under field conditions with moving personnel targets located in three areas of varied (experimental levels of) terrain complexity (Caviness, et. al., 1972). The targets for the observers were soldiers dressed in field uniforms. The subjects (N=90) were male graduates of Basic Combat Training who had received no additional range-estimation instruction and all but six had graduated from Advanced Individual Training as well. Over all conditions and target ranges (100, 200 and 300 meters), the average absolute error in range estimation for those targets which were detected was 59.6 meters (SD 56.8 meters). By distances, but over all other conditions, the average absolute error in range estimation for 100 meters was 38.1 meters (SD 44.6 meters), for 200 meters it was 69.9 meters (SD 69.2 meters), and for 300 meters it was 77.7 meters (SD 116.9 meters). The authors found that as range increased under the complex conditions presented, estimation accuracy and the associated precision decreased along with ease of target detection. That is, as distance increased, not only were there greater errors in the estimates but there was also an increase in the scatter of the estimates resulting from interactions with terrain and target complexity (Caviness, et. al., 1972). Typically, range estimations in field settings under combat conditions can not be expected to be isolated from associated tasks and extraneous cues. Caviness, et. al. (1972) attempted to provide insight into target detection under realistic conditions and found that some of the variables can be difficult to control and that accuracy diminishes drastically in field settings which provide cluttered fields with competing stimuli.

RELATED RESEARCH

In research where range judgments become a component of larger collective tasks, the accuracy of the judgments is often reduced (Caviness, et. al., 1972). Other factors have been found to play roles in contributing to increased error magnitudes in range judgements. This has been particularly true when sighting devices have been used to assist in making relative size judgements.

In efforts to determine causes for poor gunner performance using the M72A2 Light Antitank Weapon (LAW), Giordano (1975) examined sources of range measurement errors using stadia sights. Misuse of the stadia lines in bracketing the target, misinterpreting the design parameters of the stadia (US Army training doctrine interpreted the sight use differently than the sight manufacturer), and target movement contributed to errors in ranging. Depending on the target orientation (frontal or side view to the observer) these errors in sight use could create either underestimations or overestimations. It was also remarked that hand-held weapons, such as the LAW, suffer from "holding error" which is caused by the gunner's natural unsteadiness. The wobble induced by the gunner creates the image of an apparent reduction in the distance between the stadia lines, thus causing underestimation of the range to the target (Giordano, 1975). Thus the steadiness of the gunner affects his ability to make range judgements using sighting aids. In consideration of steadiness as a contributing factor, it may well have contributed to individual performance differences in other relative size ranging research (Schmidt, 1956).

In a later study to determine the optimum sighting system for an advanced LAW, Giordano (1976) found that state-of-the-art stadiametric and ranging optic sights had no significant, and little measurable advantage over "iron sights" consisting of a front post and rear peep sight. Used at the ranges being tested, 130 meters to 450 meters, the use of the post/peep sight and range estimation in near (0-300M), mid (300-400M), and far (400-500M) range band as determined for this experiment, estimates equaled those made with the more sophisticated telescopic sight designs. Design performance limits, when tested by adding realistic gunner-induced errors were reduced considerably in both precision and accuracy (Giordano, 1976).

Previous research has identified individual differences as a factor which is often awkward to measure in terms of its contribution to total variance (Frederickson, 1970). Large variability between subjects has been found in much of the research reviewed in the areas of spatial perception and depth judgement (Kottas & Bessemer, 1979; Stavrianos, 1945). A briefing on factors effecting target acquisition indicated that visual acuity was a major variable in the ability to acquire and attend to targets (Lasken Note 1). This ability relates to subsequent range determinations and perceptual information processing in complex settings (Caviness, et. al., 1972; Fried, 1961).

Accommodation, which represents one of the visual system responses to a stimulus has been considered in past reviews to have less than a direct effect on distant range judgements (Hodge, 1981). Under most conditions the accommodation reflex acts rapidly and accurately to focus the eye to the distance of the target. However, sustained and inappropriate myopia occurs under certain stimulus conditions (Leibowitz & Owens, 1975). These anomalous myopias are maladaptive in that they actually degrade rather than enhance the quality of the retinal image perceived by the observer. Of particular interest is the nearsightedness that occurs when an observer is looking into clear sky, across other unstructured fields, through optical instruments such as small aperture sights, or in low illumination. Leibowitz and Owens (1975) found in their research that individual differences were large and that the optical distance for viewing devices should correspond to the dark-focus accomodation of the individual.

The effect of anomalous myopias, or of forms of instrumental myopia, has been found more recently in on-going research to develop a simple range sighting device for the M203 Grenade Launcher (Schendel, Morey, & Heller, Note 2). A sighting device was designed using the principle of relative size perception of a man-size target at a known distance. Targets of known dimensions viewed through trigonometrically determined holes would be at a specific range and therefore easily engaged. Field testing has revealed a systematic error in judgements made by observers which suggests attribution to instrument myopia which results from focusing the eye through a narrow aperture (peep) sight (Schendel, et. al, Note 2). Further testing is being conducted to investigate the effects and possible solution to this condition.

DISCUSSION

US ARMY TRAINING APPLICATIONS

At the core of US Army training to develop range estimation skills is common task 071-326-0512 presented in the Soldier's Manual of Common Tasks, Skill Level 1 (FM 21-2, 1981). A soldier is required by this task to estimate the range to targets at distances between 50 and 3,000 meters with no greater than a plus or minus 20 percent error magnitude. Targets used to test soldiers under these conditions may be fully or partially exposed, during daylight, and are to be stationary vehicles and equipment, personnel, or silhouette targets. FM 21-2 (1981) outlines four basic methods used to estimate range under field conditions. In essence, these methods have not changed markedly over the years and were commonly taught at the turn of the century, (Bostock, 1915; Turner & Fulmer, 1917). The methods currently presented in FM 21-2 (1981) include:

- The football-field method - An observer is told to become familiar with 100 yard (meter) intervals on the ground and then for ranges up to 500 meters estimate the number of football fields between the observer and the target. For longer ranges (500 to 1000 meters) divide the distance by determining the halfway point and use the method of estimation for 500 meters or less, then double the results.

- Recognition/appearance-of-objects method - This procedure addresses the depth cues which affect perception as a result of extended distances. The general effects of atmospheric attenuation are briefly presented in a list of cues in the soldier's manual (FM 21-2, 1981).

- Flash-to-bang method - In this method, range is determined by measuring the time between the observed flash of a weapon firing and the reception of the sound from that firing. The sound travels at roughly 330 meters per second, so counting seconds and multiplying by 330 will provide a reasonable distance estimate.

- Binocular-Reticle/Mil-Relation Method - The width, length, or height of a target must be known to use this method. The Mil, which is short for milradian, being a unit of angular measurement allows the observer to compare known size targets relative to the binocular Mil-reticle and determine the distance to the target.

The soldier's manual (FM 21-2, 1981) provides more detail to these methods, particularly the binocular-reticle/mil-relation method. For the most part, however, after presenting a few cues little information is provided to assist either the soldier who must perform the task to the standard prescribed, or to help the trainer to assist soldiers to prepare to meet the standard. The information which is provided includes suggestions that the soldier "become familiar with" 100-meter intervals and learn the "effects of terrain and weather conditions." No information is made available to explain how he is to become familiar with these and other aids to improving range-estimation skills. It has been left to the instructor and to subsequent unit leaders to determine how the soldier will acquire these skills.

Observations of soldiers currently undergoing Initial Entry Training (IET) in the One Station Unit Training (OSUT) Program at the Infantry Training Brigade, at Fort Benning, Georgia, reveal that they receive relatively limited exposure to these range-estimation techniques. Range-estimation training is often limited to a small portion of a bleacher presentation during Basic Rifle Marksmanship (BRM) training. This situation is certainly not unique to OSUT since it has been the typical approach to training for range estimation for some time. Little time is available for devotion to practical exercises which are necessary to provide corrective reinforcement (Kappaul, 1945; Gibson & Smith, 1952; Gibson, 1953; Gibson, et. al., 1955; Schmidt, 1956) and to develop some experience with field-based scalar measurement standards (Gibson, et. al., 1955; Oatman, 1963). According to the literature these procedures must be practiced to correct inherent errors (individual and common) to be effective. While the standard of 20 percent error, plus-or-minus does not appear high by former standards (Bell, 1903; Caviness, et. al., 1972) it is one that every soldier is expected to achieve.

In marked contrast, past training programs for range-estimation were more closely linked with marksmanship and the development of collective skills for field use and they were practiced extensively prior to testing (Bell, 1903; Bostock, 1915). As noted earlier in the review of military literature, the performance of a soldier on estimating ranges was typically linked with his actual marksmanship performance to determine the qualification level he would be awarded (Bell, 1903). Once a soldier successfully fired to qualify as a sharpshooter, which was the highest skill level, he also had to identify the range to five consecutive targets located at different ranges between 500 yards and 1000 yards with an error magnitude of no greater than 10 percent. Similarly, marksmen, first class, and second class shooters were required to achieve range estimates with errors no greater than 15, 20, and 25 percent respectively, for the same task as well as achieving commensurate shooting scores (Bell, 1903). Bell (1903) indicated that once a unit was sufficiently prepared through regular practice (drill) the qualification test would soon be given.

The contents of training programs for earlier eras were not dissimilar to what has been presented in the soldier's manual (FM 21-?, 1951). The unit-of-measure method, which dealt with distance in terms of 100-yard intervals was used (FRFSM, 1904). A second method used in this era was the appearance-of-objects (men in the field) at different distances. Examples were presented for practice, using personnel as target. under different lighting and terrain conditions, to reinforce lectures on the subject (FRFSM, 1904). Average recognition points which an observer could distinguish under ordinary conditions of visibility, were presented with the understanding that weather and terrain conditions would mediate the observer's perceptions. Though the target illustrations have been changed from horse cavalry to tanks, the principles are the same today. Target appearance cues from past training which would tend to cause a target to be perceived as either closer or more distant agree with the current list in the training task (FM 21-2, 1981; FRFSM, 1904).

The flash-to-bang method also has remained relatively unchanged, though distance measurements are now expressed in metric terms rather than in yards (FM 21-2, 1981; FRFSM, 1904). The conversion to metric has simply changed the computation of distance in that once the time between flash and bang is noted in seconds, it is now multiplied by 330 meters (FM 21-2, 1981) rather than by 366 yards (FRFSM, 1904). Both procedures provide accuracy which is reasonable over the distances faced by infantry soldiers.

The binocular-reticle/mil-relation is a more recent addition to the general repertoire of methods to determine range which is used by the average soldier. While this procedure has not been developed recently, it was often considered more appropriate for use by the personnel who were provided range finders and other optical instruments. These devices were frequently retained at command and control levels or with artillery spotters. The use of this method was not as commonly addressed in US Army training texts as were others (Turner & Fulmer, 1917). By World War II the use of mil-reticle binoculars was more common to the soldier in battle. Testing of the effectiveness of mil-reticle binoculars to determine range to known size targets has shown that with proper training this instrument can be effective (Schmidt, 1956). A six foot tall man, for example, would appear to the observer to be five milradians tall in the standard binocular reticle (see figure 1.) if he were 400 yards (366 meters) away. Individual differences could cause variations in estimating this distance (Giordano, 1976; Leibowitz & Owens, 1975).

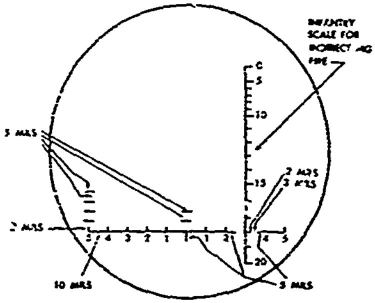

Figure 1. The binocular Reticle.

A more general application of the mil-relation is the use of commonly available objects to aid in estimating range. Earlier training addressed raised fingers at arms length to assist in communicating shifts from known locations on the battlefield (Bostock, 1915). This method would have the observer indicate that a target of opportunity, for example, was "three fingers right of" a commonly known reference point to the front. This procedure is functional as it is, but it has been refined to provide range information as well. In the Tank Gunnery Field Manual (FM 17-12, 1972; 1977) miscellaneous equipment, such as pencils, identification tags, book matches, and small arms ammunition have been suggested as aids to be used by being held up at arms length to provide known mil width indicators. These aids, as well as the use of raised fingers require practice by the user to "calibrate" them to his or her own arm length. The use of the two edges of a pencil, which has a fixed width, will provide a different angle for measurement from the eye when held vertically at arms length by an individual who has 32 inch arms than by an individual who has 35 inch arms. An example which may be most helpful to infantry riflemen is the use of the front sight on the M16A1 rifle. Measurements taken during an investigation into the reliability and performance of the weapon have shown that the width of the front sight post is .065 inches (mean width of rifles sampled) which matches closely the perceived width of a standard "E" silhouette target (19.375 inches) at a range of 175 meters when viewed through the rear sight aperture which is 19.75 inches from the front sight post. (Osborne, Morey & Smith, 1980). The use of a narrower front sight post, or fixed blade, could be used to assist a rifleman in determining how close a target is in relation to his (the rifleman's) established battlesight zero which is commonly 250 meters. A rifleman who sights on a target and sees the sight-target relationship illustrated (Figure 2.) can estimate that the target is close to 175 meters in distance. Hence, a different estimate of distance to a target is likely when perceptual differences are considered as well. Possibly more critical to accuracy than arm length is familiarity through practice with any of the aids in order for the observer to develop familiar known-size relationships (Gogel, 1964; Schmidt, 1956).

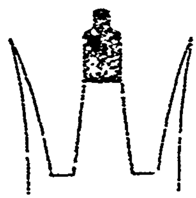

Figure 2. Front Sight Post/175 Meter Silhouette Relationship

A technique which has been described in earlier literature but appears to have been lost in recent US Army training doctrine and literature is a method used to estimate longer distances (FRFSM, 1904). An initial estimate is made to determine the maximum possible distance the target can be from the observer as well as a second estimate to determine the minimum distance it can be. These estimates must be kept within the closest limits possible and the mean of the two estimates is used as the judged distance. A variation of this approach is to use the maximum/minimum estimates and subsequently the mean of the estimate means, of several individuals observing the target (FRFSM, 1904; Shore, 1948). In other words, the average of the estimates of a few observers is used.

The current methods used to determine range by estimation appear reasonably aligned with both earlier established training procedures and generally rely upon similar environmental cues and target dispositions. What does differ, however, is the philosophy and approach to training. Observations of current training indicate that after initial familiarization little time is spent in the initial entry training program to reinforce range estimation skills. Earlier US Army training called for regular daily practice of range estimation techniques in anticipation of field testing during rifle qualification (FRFSM, 1904; Turner & Fulmer, 1917). It was considered important to provide brief, spaced periods of range estimation training daily as part of other related field training. The training in estimation was not designed to supplant other necessary instruction, nor to stand alone, but it was integrated into field marches, range firing, and in practice within proximity to barracks and other areas of frequent use as well. A compiled work, Notes on Visual Training and Judging Distance in Relation to Musketry (Bostock, 1915) is in all likelihood the most comprehensive and definitive resource for practical land-based range judgement training produced for the military. It would appear that prior range estimation training and related experiences over a full service career contributed to the preparation of this book. Bostock (1915), Sergeant Major for the School of Musketry of Great Britain, has provided information and techniques which have been supported by subsequent formal research. Techniques for training include corrective reinforcement (Kappaul, 1945; Schmidt, 1956) and developing scalar judgement through exposure to known-size targets at a variety of ranges for relative size familiarity (Gibson & Bergman, 1954, Gibson, et. al., 1955; Oatman, 1963). Two key points in Bostock's (1915) work are the importance of visual skill training and articulating why a particular judgement has been made. Visual skill training included practice at selecting out of cluttered terrain, finding obscured details on specially designed panorama landscape targets, and developing "awareness" of details in the visual field (Bostock, 1915).

The purpose of visual training in this context was the enhancement of target acquisition skills which go beyond, but include, distance judgement. Many exercises in this developmental training program were designed to awaken awareness and focus attention on the details of surroundings and terrain. Instructors were tasked to begin with lectures discussing terrain and what have come to be commonly understood as the classic depth cues

(Bostock, 1915; Gibson, 1950; 1966) as part of barracks area training followed by practical exercises in observation and distance judgement. Later, similar lectures and exercises were conducted on road marches and were critiqued at halts, and in occupied field positions. Preparing range cards for defensive positions provides practice and illustrates the application of this technique. Instructors spent time building the military vocabularies of their soldiers to improve communication and understanding of common knowledges. Soldiers were encouraged to provide detailed descriptions of their observations. According to Bostock's observations, the observer who was not taught to describe objects and their surroundings clearly, did not consider the effects of light and background, and was therefore not a reliable judge of distance (Bostock, 1915).

On road marches, instructors pointed out to soldiers possible firing positions as well as other relevant terrain considerations and questioned them (soldiers) regarding terrain use and distances to specific features. The objective of this procedure was to develop in the soldier the "power of description" (Bostock, 1915). The second primary training technique which was included as part of these field exercises was questioning the soldier about his range judgements as well as providing error correction. A unit might well be marching and be asked to judge the distance to a given terrain feature or building. Once each soldier had recorded (usually by adjusting his rifle sights to the appropriate range), or had spoken his estimate, a halt would be called to discuss the reasoning used in establishing the estimates. Soldiers not only had to develop judgement skills, but they had to understand what cues or principles were being applied in the judgement that they had made in order to respond intelligently to inquiry. This technique caused conscious personal evaluation of range estimations (Bostock, 1915). These techniques no longer appear as part of the formal range estimation, or distance judgement training conducted during US Army IET. They are used, however, by the US Marine Corps and are limited to very specialized training programs because of the training time required.

USMC SCOUT/SNIPER TRAINING

Probably the best example of adequate institutional range estimation training today is the program which teaches these techniques as a part of the training at the US Marine Corps (USMC) Scout/Sniper Instructor School at Quantico, Virginia. This program serves to illustrate both appropriate content as well as focus on the acquisition of skill through practice (Bilodeau, 1969). The lesson plan used for the formal class presentation (USMC, Note 3) addresses generally the same topics which are present in the US Army common task for range estimation (FM 21-2, 1981). An additional learning objective for the period of instruction is range estimation with the aid of a map. This task is addressed separately by the US Army (FM 7-11B 1/2, 1979) and is considered a separate skill and not a part of the common range-estimation task. The USMC lesson plan presents the 100-meter unit-of-measures method and the appearance-of-object method in greater detail than does the US Army common task. The differences in detail are less pronounced, however, when comparable lesson plans are available. The USMC lesson discusses the bracketing method related to maximum and minimum estimates (FRFSM, 1904) and the averaging of observers' estimates which has been a common sniping technique (Shore, 1948). Range cards are determined by the USMC to be helpful in determining range to targets of opportunity by reference to previous known-distance terrain features or objects. The use of range cards is taught separately by the US Army and is considered a separate task though the range card is used as a tool to assist in determining target ranges.

The mil-relation formula is presented by the USMC Scout/Sniper School in detail and is oriented toward the use of six-foot silhouettes as targets for training. Since personnel are the primary targets of snipers it is natural to train to this target type and size. The lecture portion of the USMC Scout/Sniper range estimation training is rounded out with discussion of the nature of targets and perception of them under varied conditions.

What is unique about the USMC Scout/Sniper training is the amount of practice provided and the associated standard for performance. After appropriate training the candidate scout/sniper is expected to estimate ranges during ten different exercises which use silhouette targets located anywhere between 100 meters and 1000 meters distance with no more than 10 percent error in any range band. The exercise usually consists of six targets with ranges known to the instructor. The USMC standard of 10 percent allowable error and associated testing is much more difficult to achieve than the US Army standard of 20 percent allowable error (FM 21-2, 1981), however, the training and tools which prepare the USMC scout/sniper are much better as well. As noted in earlier research this standard can realistically be attained by some observers (AMRL, 1945; Goldstone and Oatman, 1963). Once the initial lecture on range estimation is presented early in training, (USMC, Note 3), the candidate scout/sniper is expected to apply the techiques as part of every field problem and range firing exercise for the remainder of the course. In practice, each individual receives immediate corrective reinforcement for errors in range estimation just as he does with shooting performance errors during daily exercises for approximately five of the six weeks of training. This can mean that by the time a candidate is tested, he has been exposed to hundreds of ranging and subsequent engagement decisions and has received corrective feedback on his performance for each. To aid him at this task of target engagement out to 1000 meters, the sniper operates as part of a two-man team with one firer and one coach/spotter or observer. The sniper is equiped with a fixed 10-power Unertl telescopic sight on his rifle which has dots superimposed on the crosshair reticle at five mil intervals. This allows the firer to develop relative-size relationships to known-size targets and thus determine range to the target (Gibson, et. al., 1955). The coach/spotter uses a 20-power spotting scope for acquisition and firing adjustment as well as standard mil-radian binoculars which are used to develop relative-size relationships to known-size targets as does the Unertl telescope. While the binoculars do not have the same magnification (7-power binocular magnification versus 10-power for the Unertl scope) they are reported to be effective in establishing known-size-distance relationships for the team. The sniper team with these tools and proper training can now use the techniques taught and reinforced during training to arrive at a very accurate estimate of the distance to any target presented in a variety of field settings. The ranging techniques are enhanced by other portions of the training as well. Observation skills and range-card development contribute to making accurate range estimates (USMC, Note 3).

An important part of the USMC scout/sniper training is the development of observation skills. The candidate scout/sniper team is placed in an observation post for the practical exercise and is given 40 minutes to locate and properly identify up to twelve military items partially hidden in the terrain assigned for the task (USMC, Note 3). Using the 20-power spotting scope to assist with identifying irregularities found, the team scans and searches the entire area. This exercise, repeated as part of the training routine, develops an awareness of abnormalities in target fields of view and helps the scout/snipers acquire appropriate targets. Similar exercises have been presented as part of marksmanship training in the past in order to develop specific observation skills and "generally to heighten visual perception" (Bostock, 1915).

The range-estimation training presented by the USMC Scout/Sniper Instructor School is much more extensive and demanding of the student than is the US Army program. It is also important to note, however, that attendance at the USMC school is the result not only of voluntary application for participation, but acceptance comes after candidates pass a strict screening process. One criterion which must be met is 20/20 visual acuity, which can be corrected acuity in some cases. This criterion and others related to the applicant's motivation to attend and complete the course affect the performance parameters and variance which would normally be attributed to collective individual differences in the general population. Some form of natural selection appears to have taken place which when combined with proper training results in very accurate range estimation performances. Under the circumstances of USMC training where a select population, adequate training time for extensive practice, and corrective reinforcement by skilled instructors are present, it is reasonable to assume that the relatively high standard of performance which has been established is probably appropriate. Reported performance measurements indicate that this assumption is correct (USMC, Note 3).

The US Army IET training, however, takes place in a very different environment. Since the population present for the US Army IET includes all new soldiers, there is little regard for individual differences such as visual acuity or other physiological diversities and perceptual set which contribute to the ranging error variance (Frederickson, 1970). For example, related research which has addressed marksmanship training, normally conducted with range estimation as a concurrent training subject, indicates that some soldiers have not received needed corrective lenses in time for this instruction (Smith, et. al., 1980). OSUT training is both limited in time and broad in scope with very little time available for practice and individual corrective reinforcement during range-estimation instruction. Range-estimation instruction is realistically an introduction or familiarization with those cues and associated behaviors which must be learned and practiced to acquire skills at estimating range. It would be inappropriate to expect performances similar to those achieved by highly trained select groups such as the US Marine Corps Scout/Snipers.

What the US Army small unit leader faces, either the squad leader, platoon sergeant, or the platoon leader, is a soldier entering his unit who has heard about what affects range judgements and has possibly paced a measured 100-meter course. Subsequent to this exposure, the soldier has probably received very little training specifically related to range estimation. These comments are based on personal observations. They are not made to condemn any efforts to train the soldier but, more practically, to point out the deficiency at the unit level which results from training shortcomings and to seek solutions to the associated problems which the leader must address. The problem faced by both the trainer and the leader is what can be done to correct this apparent deficiency in a critical field skill.

A second and somewhat philosophical difference between historical training programs and the present US Army range estimation training is the common standard established for successful task performance. USMC Scout/Sniper training can not be compared in this context because it trains prescreened students whereas past and present US Army programs were for all initial entry personnel. Earlier training programs and related performance testing had measured levels of performance associated with rifle (musket) qualification (Bell, 1903). This permitted the unit commander additional information regarding the skill level of his soldiers. In these historical cases he had some sense of a soldier's estimation abilities. The present standard has been established as part of the range estimation task statement with an allowable magnitude of error high enough for (almost) all soldiers to successfully meet (plus or minus 20%). The shortcoming with this pass or fail standard is that it does not recognize measured ability to accurately estimate range. In the training environment this may be appropriate, but the unit leader could well benefit from knowing which of his soldiers can best estimate range just as he could in knowing who is (are) the best shot(s). It must be assumed that some unit commanders are concerned about the level of skill and ability in areas such as range estimation, and they presently may have training programs to identify and improve these skills in their soldiers but this is not accomplished across the US Army in a systematic fashion.

TRAINING PROCEDURES

Perceptual literature which has focus on field experimentation, as well as historical and contemporary military training literature and examples indicate that sufficient information is already available to formulate solutions to the problem of training soldiers to estimate range with greater precision than that which is required by current standards (FM 21-2, 1981). In part, the problem is training the soldier to properly estimate range and, in part, it is efficiently managing available training time to obtain the best results using appropriate techniques. The evidence from both research and extensive military experience indicates that the application of proven training procedures can enhance an individual's ability to estimate range (Bostock, 1915; Ferris 1971; Gibson, et. al., 1955). Critical and effective elements in past and current training appear to include corrective reinforcement (Gibson and Smith, 1952; Kappaul, 1946; Schmidt, 1956), exposure during training to targets at known distances to develop scalar dimensions or experienced limits to individual perceptions of depth (Gibson, et. al., 1955), which can be transferred from one environment and task to another (Gibson & Bergman, 1954), and training either with aids or without when necessary using known size targets to enhance relative size perceptions (AMRL, 1945; Bostock, 1915; Epstein, et. al., 1961; Kappaul, 1946; Kilpatrick & Ittelson, 1953; Schmidt, 1956). Spaced range estimation training as part of related training, which requires the soldier to make range judgements while marching to field locations for example, has been effective (Bell, 1904; Bostock, 1915). A relatively small amount of practice which includes exposure to scalar depth tasks appears to have a positive effect on the ability to improve range estimation performances in practical settings (AMRL, 1945; Gibson, 1953; Gibson & Bergman, 1954; Gibson, et. al., 1955; Kappaul, 1946). Continued brief practice episodes using known size targets and aids to develop relative size relationships as part of larger tasks, over time, appears to be the most effective approach to range judgement skill learning and enhancement (Bostock, 1915; USMC Note 3). The effect of spaced practice, while acquiring a skill appears to aid in the long-term retention of the skill (Note 4). Landauer's expression that distributed practice is best for long-term retention suggests support for the general notion that distributed refresher training would be beneficial to long-term retention (Note 4).

Training which enhances range estimation skills has been combined in programs and in field practice with other procedures to produce more accurate range determination judgements. These include range card preparation which can be a relatively simple sketch showing a few references points and sector of fire limits for a crew-served weapon as illustrated in FM 23-67 (1964) (Figure 3).

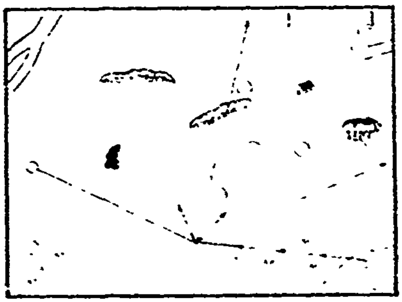

Figure 3. Range Card M60 Machinegun.

More complex and detailed range cards can, and should, be prepared when time and aids (maps, range finders, binoculars, actual terrain pacing) are available. An example of a more detailed range card taken from FM 17-12 (1977) illustrates the additional information which may be used to improve range estimates to targets of opportunity (Figure 4). Tank gunnery requires additional information which is present in figure 4. but this does not mean that additional information would not be helpful to other battlefield users.

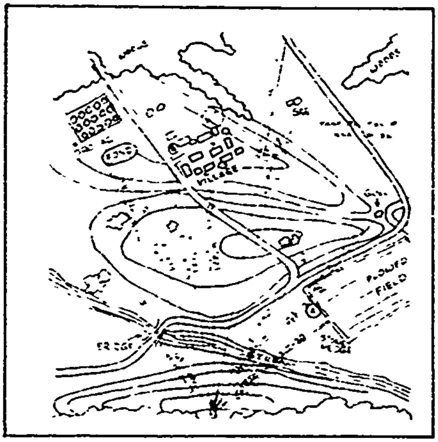

Figure 4. Range Card, Tank (FM 17-12, 1977).

The use of tactical maps to develop range cards and make range judgements has been emphasized both historically (Bell, 1903; Bostock, 1915) and in present training (FM 17-12, 1977; USMC, Note 3). Findings from research indicate that accurate map reading and subsequent terrain association are critical skills needed by artillery (and infantry mortar) forward observers who are called upon to make range estimates during target engagements (Mocharnuk, Marco & Trelz, and Walkoetter & Milligan, 1979).

TRAINING ENVIRONMENT

The application of proven training techniques to enhance range estimation skill acquisition has been successfully demonstrated. The problem faced by the US Army is then how best to conduct the appropriate training. Present constraints on training resources, particularly time and an insufficient quantity of experienced instructors, limits the methods available for application during IET. Training time in IET is usually blocked, that is to say, labelled by purpose and content and allotted a specific space in the total training program for its intended purpose. An appropriate procedure to introduce range judgement by estimation is already a part of the IET training program and consists of a lecture presentation on the basic methods (100-Meter Intervals, Appearance-of-Objects, Flash-Bang, and Binocular-Reticle/Mil-Relationships) and a practical exercise (if time permits) of pacing 100 meters, as well as observing personnel and vehicles at a variety of ranges. The next logical step, which has been used, is spaced, or distributed practice (Landauer, Note 4) which accompanies but need not interfere with subsequent subjects being taught. Practice might reasonably consist of estimates being made in the training battalion area while breaking from drill. Corrections could then be presented and discussed by drill sergeants (Bostock, 1915). Later, on road marches which follow routes familiar to the drill sergeants, soldiers could be asked to make estimates to prepositioned targets at ranges known to the drill sergeants. Silhouettes of personnel and vehicles could be positioned and remain for future use with little loss of training, or additional duty time for cadre (required for target emplacement). The procedure of presenting range estimation training as a repetitive ancillary to other field training, rather than concentrating it in one brief exposure, would assist the development of awareness of depth in the soldier and aid retention.

The primary purpose of considering IET as the place to train range estimation skills and related target acquisition skills would be to better orient the soldier to the importance of these skills. IET could properly present and then reinforce the principles and fundamentals more effectively than it does presently by distributing training and practice. Acquired skills could be improved upon once the soldier reached his assigned unit. At the unit the soldier would already be familiar with the fundamentals of range judgement and could develop experience in the environment to which he had been assigned. In other words, he would "calibrate" and improve his judgements by applying the principles and cues he had learned in IET to the terrain he would now have to occupy. The importance of adaptation to specific environments during or after training has been recognized in the discussions of previous research (Gibson, et. al., 1955; Goldstone & Oatman, 1962). While past researchers found relatively high levels of transfer from training to testing in specific experiments, it was recognized that there was little difference in the terrains used for training and testing. Appropriate cautions about less direct transferability to new environments without additional training were noted (Gibson, et. al., 1955; Goldstone & Oatman, 1962).

The IET environment is an important source for the presentation of initial training, but the typical FORSCOM unit does not necessarily consider a new soldier fully trained and capable of performing all tasks as he arrives. A newly-assigned soldier is typically introduced to his job as a squad member through controlled practice. Since range estimation is an important and integral part of target acquisition (Caviness, et. al., 1972) it should be practiced as well. Past research indicates that is is possible to transfer the skills acquired during training from one environment to another, but as it has been noted, the effectiveness of this transfer has not been adequately established (Gibson, et. al., 1955). Training within the unit would allow adaptation of the fundamentals of range judgement by estimation to the unit's operational environment. The task outlining range estimation in the soldier's manual (FM 21-2, 1981) lists the effects of atmospheric attenuation and terrain on the perceptions of the observer. It does not address individual perceptual differences and does not provide the squad leader, for example, with methods to determine which of his soldiers can accurately estimate range. A systematic training program within the unit would refresh and adapt acquired skills and allow leaders to determine which soldiers make reliable and accurate estimates of range.

CONCLUSIONS AND RECOMMENDATIONS

This investigation of range determination by estimation has shown that procedures which appear to be effective had been developed in the past (Bell, 1903; Bostock, 1915) and are currently in use in some circumstances (USMC, Note 3). Research on range estimation has been conducted in field settings which permit judgements of the effectiveness of training techniques as well as indicating the utility of these techniques for future training programs. This information can assist soldiers being trained in institutional settings (IET/OSUT) as well as in units to enhance the accuracy of their perceptions of distance, by using estimation techniques and aids. The conclusions which follow have been drawn from perceptual literature and experimentation, military training experience and related field research, as well as observations of on-going training in range estimation skill development. It was surprising to note that successful training procedures which have existed for decades were no longer a part of training and that they have had to be rediscovered. Additional research may be useful to further enhance the ability of soldiers to estimate range accurately, however, the findings from this current investigation can be considered for immediate implementation, since the procedures and methods have been demonstrated to be effective.

o It is possible to enhance the range estimation skill levels for soldiers through the use of training procedures which presently exist.

o All individuals, however, can not be expected to demonstrate the same level of ability as a result of the same limited training, particularly under field performance conditions (Caviness, et. al., 1972; Frederickson, 1970). Individual differences will require additional training. Leaders may be forced to accept poor performance and marked differences in performance which will occur in some cases.

o The current standard for range estimation performance which allows an error magnitude of plus or minus 20 percent (FM 21-2, 1981) has been achieved historically by most soldiers when proper and complete training was provided. Based on past measured performances implementation of an effective comprehensive range estimation training program may realistically permit the establishment of more stringent and discriminating standards in the future. The philosophy of past eras indicates that there was merit in being able to differentiate between soldiers with keen estimation ability and those who could not estimate distances as accurately (Bostock, 1915; Turner & Fulmer, 1917).

o Past training, as well as the current training procedures and methods, have focused on enhancing perceptual awareness through exposure, repeated at frequent intervals to targets which might typically be encountered under expected conditions at realistic distances. This practical application of training to establish relative-size relationships with known-size targets is well founded in perceptual research findings developed through field experimentation (Bell, 1903; Gibson, 1953; Gibson, et. al., 1955; Kilpatrick and Ittelson, 1953). Repeated exposure to these training conditions tends to aid skill retention (Kappaul, 1946).

o Range estimation can be improved by the use of aids which assist the observer in establishing relative-size relationships with known-size targets. Weapon sights and binoculars have been shown to improve estimates in field settings and at the ranges which the infantry soldier may expect to operate (Schmidt, 1956; USMC, Note 3).

o Field research has shown that soldiers can be trained to determine ranges to targets with improved accuracy, but environmental conditions such as target movement, cluttered terrain, and variations in atmospheric conditions may influence the estimates and usually tend to degrade accuracy (Caviness, et. al., 1972; Fried, 1961; Turner and Fulmer, 1917). Once the fundamentals are practiced, range estimation should be trained under degraded conditions. This has also been suggested for the related skills of target identification with which range estimation training might easily be combined (Cockrell, 1979).

Probably the most important recommendations which have developed from the findings of this research deal more with the manner in which range estimation training takes place and the influence of command policy toward it, rather than with the specific content of the training program. It has been repeatedly shown that observers (soldiers) have been and can be trained to estimate range with improved accuracy, though individual differences in perceptual set and general ability will mean that some of them will perform better than others. Under controlled conditions, relatively accurate performances may be expected, such as estimates with less than 10 percent error out to 1000 meters (USMC, Note 3.). In combat settings, these performances would most likely be degraded by environmental and target influences. It is the responsibility of the training personnel and the junior leaders to develop in each soldier the highest level of ability to estimate range accurately as well as train all necessary soldier skills. The development of an awareness of distances and relative-size of targets is most important. The type of training environment a soldier has and the influence of critical leaders and trainers is also important for the general development of combat skills.

Range estimation training during IET, after an initial lecture period presented in a classroom or while seated in bleachers appears to be most appropriately presented as part of other related training (marksmanship, map reading). The awareness of distance in estimates to targets can be taught by instructors on road marches and on the rifle range as well as during breaks in garrison and field training. The focus of training should be to make the soldier aware of target distance relationships in all settings. The orientation of leaders and policy should be to promote this awareness in trainers and in junior leaders to insure that this type of training is passed on to the soldiers in the command.

More effective training for the development of range estimation skills should not be considered prohibitive in terms of resource expenditures. The cost of improved training programs should be minimal if this training becomes part of other related training. A drill sergeant and later a squad leader or platoon sergeant, can make use of rest stops on road marches or use time while moving from one location to another to "coach" those skills and cues a soldier should be attending to while moving through a tactical environment. This approach to training reinforcement would also assist cadre in the general soldierization process which is one focus of IET. Being aware of the surroundings and attending to distances , making range judgments to potential targets, establishing relative-size relationships to silhouettes or known-size targets along the route of march, all tend to develop an attitude of concern for detail in the soldier.

Units receiving new soldiers should acclimate them to their new environment and provide refresher training which will reinforce the skills learned in training. This will provide opportunities to become familiar with those terrain and atmospheric characteristics which are unique to the new environment and which will alter previous experience regarding perception of distance. For example, the results of the application of the classic depth cues which Gibson (1950) identified will be different for conditions found in Germany in the winter and for the dry heat of the middle east. Additional benefits can be realized by making range estimation practice part of a unit's routine operation as well. The small-unit leader can become familiar with the ability of the soldiers to make accurate range judgments and learn to rely on the more capable individuals to assist in the development of range cards and related aids when occupying a field position. Knowing the capabilities of soldiers and using them effectively also helps develop cohesiveness.

The research conducted for this report indicates that effective training for improved range judgments using estimation could be successfully conducted and done in a resource effective manner. It would require the attention and cooperation of commanders in training and FORSCOM organizations. The largest issue facing officers interested in potential improvements in the US Army's range estimation (and related skills) training is policy based rather than training development oriented. The Soldier's Manual of Common Tasks (FM 21-2, 1981) and the Tank Gunnery Manual (FM 17-12, 1977) already provide the basic guidance for improving range estimation training if they are applied regularly and in conjunction with other training. While there are limits to the enhancement of human perceptual ability, the standard which allows range estimation errors in excess of 20 percent (FM 21-2, 1981) can be improved upon (Turner & Fulmer, 1917; USMC, Note 3). Adopting the extensive training program used by the US Marine Corps Scout/Sniper School where performance must meet a 10 percent error standard would not be appropriate or practically possible because of the extensive training required. Applying the concepts of relative-size of known (familiar)-size targets in a familiar environment could be accomplished effectively without such extensive training by most junior leaders. Practice sessions need not be long or require complex activities. The soldier could be trained to become familiar with common landmarks and structures which would uniquely influence his decisions about distance. Familiarity with potential threat silhouettes, which are life size, as well as common threat vehicles would ultimately be more helpful than using US military vehicles and six-foot silhouettes to train. Each unit training in this way would have the opportunity to develop a situationally unique program based on its mission and its tactical environment. Command emphasis which provides encouragement to the leader at company and platoon levels to develop and conduct such training appears to be the primary requirement for an improved range estimation training program. Instructor skill could be developed first through practice and then transfered to the soldiers in the unit. Once a training program of this type could be established it would provide a base for future development and improvement in range estimation. At present there is not sufficient range estimation training provided to initial entry soldiers, nor the soldiers in troop units to compare present training with enhanced programs.

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